UCRL-MI-231443

IFE Science and Technology Strategic Planning Workshop - Part 4: April 27, 2007 Presentations

To select an individual presentation, click the table of contents entry on the next page or click the title on the agenda for Day 4 (using the Hand Tool icon).

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Part 4 Contents

IFE Science & Technology — **Strategic Planning Workshop**

San Ramon, California — April 24-27 2007

Technical Program

Day 1, Tuesday, April 24

Overviews - Approaches to IFE

7:00-8:00 Registration and Continental Breakfast

All Day Plenary Session

8:00-8:30 Workshop Motivation and Objectives (Ed Synakowski, LLNL)
8:30-9:00 Setting the Stage for IFE and Workshop Overview (Wayne Meier, LLNL)

Following speakers to address current status, near-term plans, long-range visions and funding needs to move to the next step for the particular approach. With respect to planning, address

- How do you see your approach evolving beyond the near term?
- What needs to be accomplished to move forward on such a strategy?
- What are the potential landscape-changing developments?
- What are the technical issues for your approach?

9:00-9:30 HAPL/KrF (John Sethian, NRL)
9:30-9:40 Q&A

9:40-10:00 Break

10:00-10:30 DPSSL (Al Erlandson, LLNL)
10:30-11:00 Discussion

11:00-11:30 FTF (Steve Obenschain, NRL)
11:30-12:00 Discussion

12:00-1:00 Lunch

1:00-1:30 HIF (Grant Logan, LBNL)
1:30-2:00 Discussion

2:00-2:30 Z-IFE (Craig Olson, SNL)
2:30-3:00 Discussion

3:00-3:15 Break

3:15-3:45 FI as a Cross-Cutting Option for IFE (Mike Campbell, GA)
3:45-4:00 Discussion

4:00-4:30 The Potential Benefits of Magnetic Fields in Inertially Confined Plasmas (Bruno Bauer, UNR)
4:30-4:45 Discussion

4:45-6:00 Panel Discussion (M. Campbell, S. Dean, G. Logan, C. Olson, C. Sangster, J. Sethian, E. Synakowski)
What can/should we do to be prepared to take advantage of growing interest in and funding for IFE that could be triggered by a variety of events (e.g., successful ignition on NIF, increase concern about global climate change, increase interest in domestic energy sources, etc.)?

Day 2, Wednesday, April 25

Working Together in the Near-Term to Advance IFE and Related Science

7:30-8:00 Continental Breakfast

Interagency Approach to High Energy Density Laboratory Plasmas (HEDLP)
8:00-8:20 Overview of the National Task Force Report on HEDP: Setting the Stage (Ron Davidson, PPPL)
8:20-8:50 OFES, NNSA Perspectives (Ray Fonck, OFES; and Chris Keane, NNSA)
8:50-9:15 Updated Planning for HED-LP (Francis Thio, OFES)
9:15-9:45 Discussions

9:45-10:00 Break

Plenary Talks: Existing and near-term ICF/HEDP capabilities and research plans focusing on R&D relevant to IFE
Questions to focus the plenary talks include:

- What are the HEDP questions that can be addressed in the near-term that are relevant to IFE? How can NNSA facilities be used to support IFE both now and post ignition?
- What are current or planned interactions with the other communities (ICF/HEDP/IFE)?
- Who are the customers for this HEDP science besides the IFE/ICF community?

ICF/HEDP Facilities and R&D:
10:00-10:45 NIC and NIF (John Lindl, LLNL)
10:45-11:15 Omega (John Soures, UR-LLE)
11:15-11:45 Z-pinch (Keith Matzen, SNL)
11:45-12:15 Nike--1) ICF Experiments and Plans, 2) ICF Physics Issues (Andy Schmitt, NRL)

12:15-1:15 Lunch

1:15-1:45 Advanced Ignition (Fast and other two-step ignition) (Riccardo Betti, UR-LLE)
1:45-2:15 HIFS/WDM/Hydrodynamics Experiments on NDCX-I and NDCX-II (John Barnard, LLNL)
2:15-2:45 A Pathway to HEDP: Magnetized Target Fusion (Glen Wurden, LANL)

2:45-3:00 Break

3:00-5:00 PM - Breakout Session - Working Together to Advance IFE and Related Science*
Four groups. Same questions for each group:

- What are the HEDP questions that can be addressed in IFE-relevant NNSA and OFES facilities? Which questions are directly relevant to IFE? What types of IFE relevant experiments can be done on NNSA ICF facilities?
- How does addressing these questions enable progress in IFE?
- What opportunities exist that can be captured with growing budgets?
- How are the IFE/ICF/HEDP communities working together to maximize use of limited resources to advance the underlying science of IFE? What obstacles exist? How can these working relationships be improved?

***Breakout group leaders to prepare a single summary talk to be given the final day.**

Day 3, Thursday, April 26

International Perspective and IFE Science and Technology in the Long Term

7:30-8:00 Continental Breakfast

International Activities
8:00-8:30 FIREX Project (Hiroshi Azechi, ILE, Osaka, Japan)
8:30-9:00 HiPER and other EU Activities (Mike Dunne, UK)
9:00-9:30 IAEA Coordinated Research Program on IFE (Neil Alexander, GA)

9:30-10:00 Discussion on opportunities for international collaborations

10:00-10:15 Break

10:15 AM-12:00 PM – Contributed/Solicited talks (~ 5 @ 15-20 min each)
Other (non-driver) Enabling and Cross-Cutting Science and Technology
- A Survey of Advanced Target Options for IFE (John Perkins, LLNL)
- Ion-Driven Fast Ignition: Scientific Challenges and Tradeoffs (Juan Fernandez, LANL)
- Thick Liquid Protection for Inertial Fusion Energy Chambers (Per Peterson, UCB)
- Dry Wall Chamber Designs (Rene Raffray, UCSD)
- Status of Developing Target Supply Methodologies for Inertial Fusion (Dan Goodin, GA)

12:00-1:00 PM - Lunch

1:00-3:00 Poster Session (contributed posters)

3:00-5:00 PM - Breakout Session - IFE Planning*
Four groups. Same questions for each group:
- What are the elements of a compelling breakout strategy for IFE?
- What advances have to be made to make such a strategy credible?
- What advances can only be made with increased funding?
- Have views of an IFE development path changed since FESAC report? If so, how?

***Breakout group leaders to prepare a single summary talk to be given the final day.**

Day 4, Friday, April 27

Next Generation and Next Steps

8:00-8:30 Continental Breakfast

8:30-10:00 AM - Panel Discussion
Training the Next Generation: University Participation in HEDP and IFE Science and Technology
(5 minute introductions + Discussion)
(Bruno Bauer, UNR; Farhat Beg, UCSD; Linn Van Woerkom, OSU; Shahram Sharafat, UCLA; Brian Wirth, UCB)

10:00-10:15 Break

Summaries from Breakout sessions
(up to 30 minute presentation plus 15 minute discussion)

10:15-11:00 Wednesday Breakout Summary: HEDP Opportunities for IFE (Ed Synakowski, LLNL)
11:00-11:45 Thursday Breakout Summary: IFE Planning (Steve Dean, FPA)

11:45 AM - 12:00 PM - Concluding Remarks, Action Items, Next Steps

12:00 PM - Adjourn

Training the Next Generation: University Participation in HEDP and IFE Science and Technology

Combined presentation by:
Bruno Bauer, UN Reno
Farhat Beg, UCSD

IFE Science and Technology
Strategic Planning Workshop
Friday, April 27, 2007

HOW TO RECRUIT STUDENTS TO IFE?

- Spread the word to high school and undergraduate students
  - national mission
  - develop a dynamic web site with animations
- Support undergraduate research experiences
  - extend NUF program for IFE
  - Imitate NSF REU
  - Popular IFE lecture series for undergraduate students
- Program to attract students from Freshman level
  - good example, building robots
- Graduate student support during course work
- Access to small scale facilities at campuses

HOW TO TRAIN AND RETAIN STUDENTS IN IFE?

- Summer schools
- Hands on experience
- Availability of source codes
- Support multi campus courses
- Access to small scale facilities, STABLE FUNDING and collaboration with National Labs
  - National POST DOC Fellowship program
  - Support post doc funding at universities (by funding agencies)
  - Participation in experiments at large scale facilities

TRAINING THE NEXT GENERATION

UNIVERSITY PARTICIPATION IN HEDP AND IFE SCIENCE AND TECHNOLOGY: PANEL SESSION

SHAHRAM SHARAFAT

MECHANICAL AND AEROSPACE ENGINEERING DEPARTMENT

UNIVERSITY OF CALIFORNIA LOS ANGELES

INAUGURAL IFE SCIENCE AND TECHNOLOGY STRATEGIC PLANNING WORKSHOP

SAN RAMON, CALIFORNIA
APRIL 24 - 27, 2007

Outline

- Demographics
- Personal Experience
- But what …?

Demographics of Fusion Science Faculty at US Universities

- Age distribution of fusion science faculty (engineering and physics) at universities shows a marked imbalance weighted towards older faculty

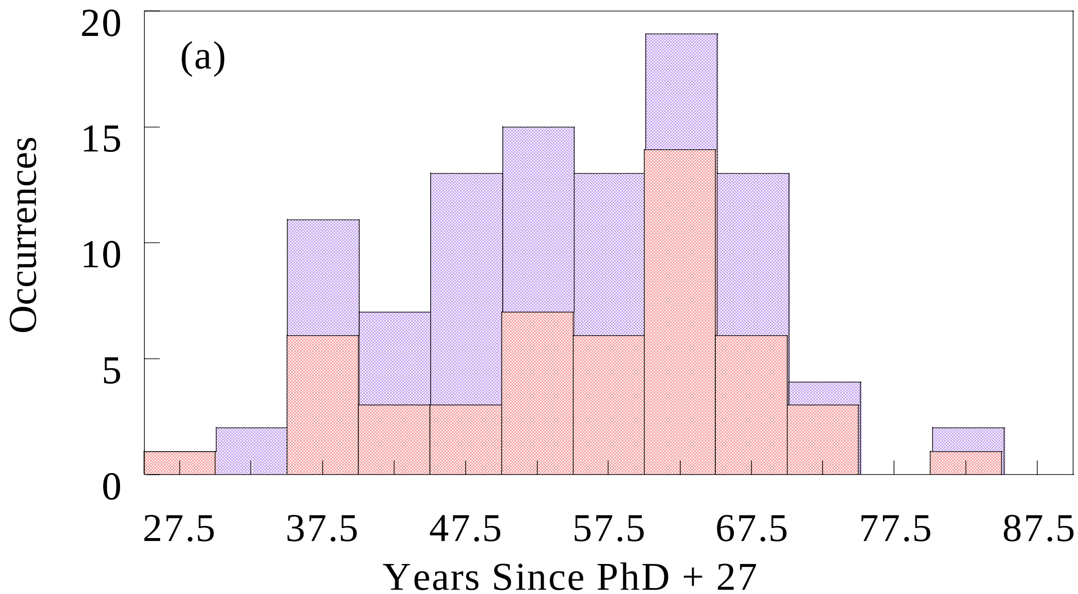
- For **MIT, U. Maryland, U. Wisconsin, U. Texas, UCLA, and UCSD** the skewness factor is **~ 2.4** (ratio of faculty 55-75 to 30-50 age bracket) [all other physics faculty skewness factor is ~1.1]

- Hiring trends at larger institutions suggest recent and projected fusion science hiring is down: in the last ten years, **only 10%** of all Assistant Prof. hires were in plasma science

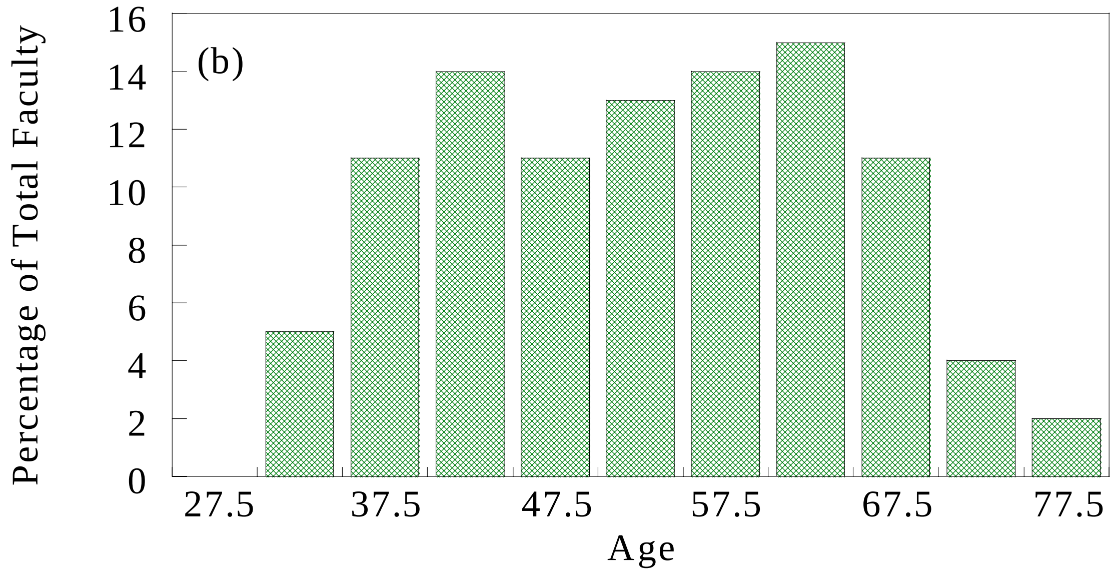
- "**Hoped-for hiring**" in fusion science over the next five years indicates a hiring-to-retirement ratio of at most **TWO to THREE**

"A REPORT ON THE AGE DISTRIBUTION OF FUSION SCIENCE FACULTY AND FUSION SCIENCE PHD PRODUCTION IN THE UNITED STATES," University Fusion Association, April 26, 2007; Earl Scime, Department of Physics, West Virginia University, Morgantown, WV ; Ken Gentle, Department of Physics, University of Texas at Austin, Austin, TX; Adil Hassam, Department of Physics, University of Maryland, College Park, MD

Demographics of Fusion Science Faculty at US Universities



Estimated age (years since PhD + 27 years) distribution of **fusion science faculty** at colleges and universities in the United States obtained from 24 institutions with a total of 100 faculty. Fusion faculty data from six major centers of plasma physics (MIT, Univ. of Maryland, Univ. of Wisconsin, Univ. of Texas, UCSD and UCLA) are shown in red as an overlay.



Age distribution of **physics faculty** at colleges and universities in the United States [obtained from the talk, "Enrollments and Faculty in Physics" given by Roman Czujko, Statistical Research Center Director, American Institute of Physics, at the University of Maryland in June, 2002]

"A REPORT ON THE AGE DISTRIBUTION OF FUSION SCIENCE FACULTY AND FUSION SCIENCE PHD PRODUCTION IN THE UNITED STATES,"

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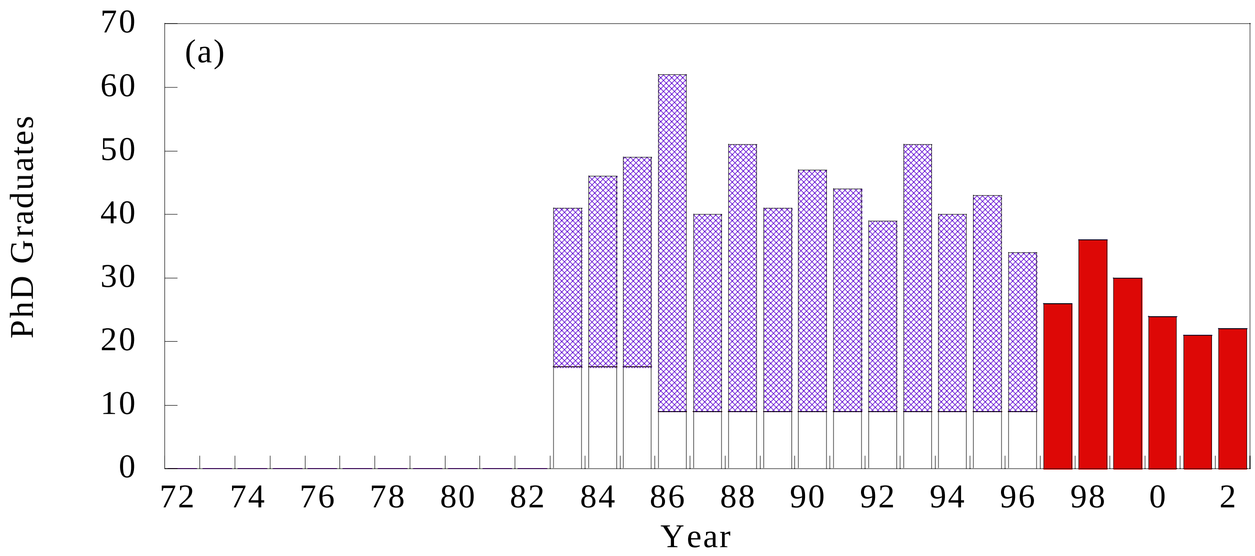
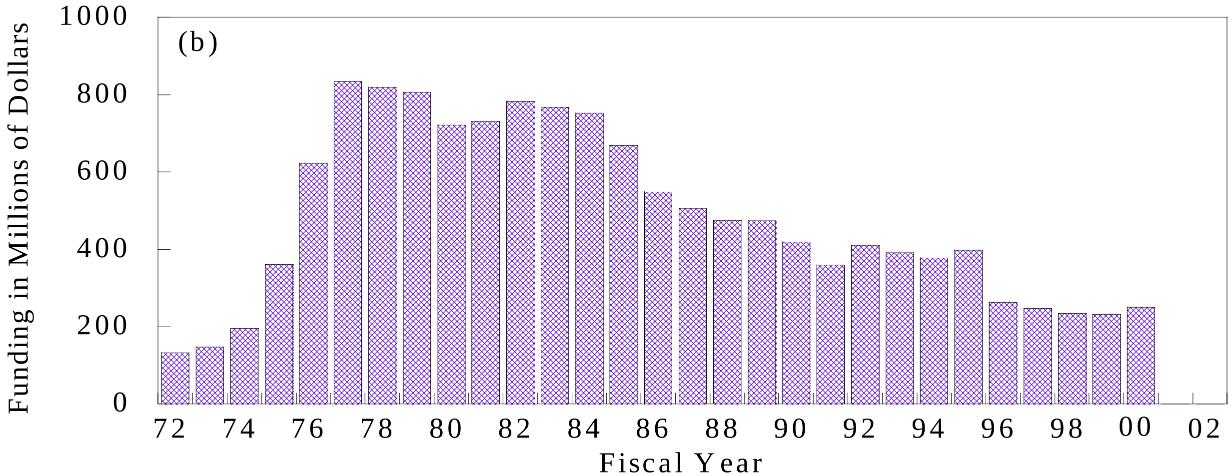
Production Rate of PhD's in Fusion Sciences



- The production rate of PhD's in plasma and fusion science shows a **steady decline starting 1986**. This (decline starts approximately 3 years after the onset of a similar steady decline in the funding level of the US Fusion Energy Sciences Program.

Funding level of US Fusion Energy Sciences program (constant FY00 dollars).



Univ. Colorado -Boulder
West Virginia Univ.
MIT
Univ. Washington
Univ. of Maryland
Princeton
Univ. Texas - Austin
Columbia University
William and Mary
Univ. Wisconsin-Madison
UCLA
UCSD
Cornell University

"A REPORT ON THE AGE DISTRIBUTION OF FUSION SCIENCE FACULTY AND FUSION SCIENCE PHD PRODUCTION IN THE UNITED STATES," University Fusion Association, April 26, 2007; Earl Scime, Department of Physics, West Virginia University, Morgantown, WV ; Ken Gentle, Department of Physics, University of Texas at Austin, Austin, TX; Adil Hassam, Department of Physics, University of Maryland, College Park, MD

Personal Experiences

- Mechanical Engineering Design Courses (~ 20% female)

- ATTRACTION to Fusion:
  1. Energy Related → Strongest Drive to enter Fusion GS
  2. Curiosity about Fusion → Strong Drive to enter Fusion GS
  3. Diversity of Fusion → Medium drive to go on to GS
  4. International Nature → Low Drive to enter field

- TURN OFFS :
  - Lack of “clear” roadmap to jobs or career
  - Unreliable Graduate Research funding outlook
  - Most UG students think *Research Jobs* are HARD

- COMPETITION: Defense Industry high paying entry level jobs

BEING A STUDENT IS NOT THE SAME AS IT WAS 20 YRS AGO

- By the time they graduate, many students carry a financial burden

- Today's UG students are more concerned about the financial aspects of their future than following their aspirations

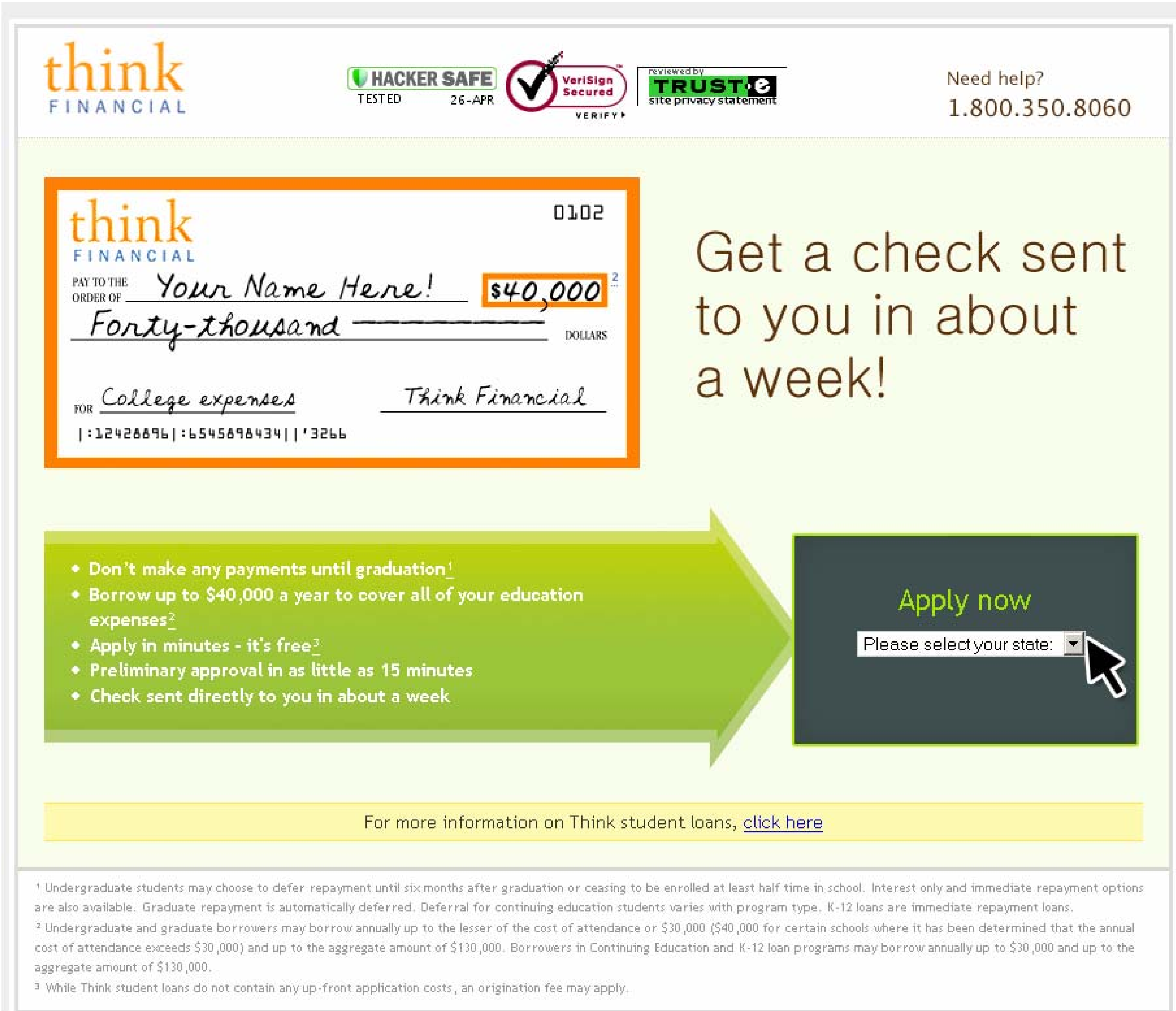
- A common statement from UGs is the ROI argument for Higher Education (~$200 K)

How much student loan debt does the average student accumulate?

The answer to this question depends on the type of institution a student attended and his or her degree program. These estimates, from the *2003-2004 National Postsecondary Student Aid Study*, are the most recent nationally representative data on student indebtedness.

Degree	Institution	% who had Borrowed	Median Amount Borrowed
Certificate	Community College	21	$5,307
	Proprietary School	78	$5,705
Associate	Community College	28	$5,879
Bachelor's	Public Four-year	58	$14,671
	Private Four-year	69	$17,125
Master's	Public Four-year	49	$26,119
	Private Four-year	73	$29,000
Doctorate	All Institutions	48	$44,743
Professional	Public Four-year	89	$63,500
	Private Four-year	81	$71,317

http://www.acenet.edu/


think
FINANCIAL
HACKER SAFE
TESTED 26-APR
VeriSign Secured
VERIFY
reviewed by
TRUSTe
site privacy statement
Need help?
1.800.350.8060
think
FINANCIAL
0102
PAY TO THE ORDER OF Your Name Here!
$40,000
Forty-thousand
DOLLARS
FOR College expenses
Think Financial
|:12428896|:6545898434||'3266
Get a check sent to you in about a week!
Don't make any payments until graduation[1]
Borrow up to $40,000 a year to cover all of your education expenses[2]
Apply in minutes - it's free[3]
Preliminary approval in as little as 15 minutes
Check sent directly to you in about a week
Apply now
Please select your state:
For more information on Think student loans, click here
[1] Undergraduate students may choose to defer repayment until six months after graduation or ceasing to be enrolled at least half time in school. Interest only and immediate repayment options are also available. Graduate repayment is automatically deferred. Deferral for continuing education students varies with program type. K-12 loans are immediate repayment loans.
[2] Undergraduate and graduate borrowers may borrow annually up to the lesser of the cost of attendance or $30,000 ($40,000 for certain schools where it has been determined that the annual cost of attendance exceeds $30,000) and up to the aggregate amount of $130,000. Borrowers in Continuing Education and K-12 loan programs may borrow annually up to $30,000 and up to the aggregate amount of $130,000.
[3] While Think student loans do not contain any up-front application costs, an origination fee may apply.

“But What’s Your Alternative”

- Strong GS Fellowships and Stipends Fund:
  - Establish an IEC “Fellowship Fund”
  - Collect ~0.5 – 1% from ALL (HEDP, ICF, IEC) Funded Program to support GS Fellowships and Stipends.

- Develop PR / Advertisement Packages:
  - Create a dedicated Website for HEDP, ICF, IEC with lots of Videos [current “Contemporary Physics Education Program (http://www.cpepweb.org/)”]
  - Develop and present a set of Fusion Primer Seminars with Videos
  - Emphasize the “INTERNATIONAL Nature” of Fusion Science
  - Highlight spin-offs form fusion research

Additional SLIDES

REASONS WHY BORROWING HAS INCREASED:

(1) Increases in federal grant aid have not kept pace with rising postsecondary education costs

(2) Widening gap between college prices and grant aid

(3) Students' financial need have increased as educational costs have grown

(4) Increases in loan limits and ease of borrowing have allowed more students to receive loans.

MFET Fellowship Program

- In 1980, the Magnetic Fusion Energy Technology (MFET) Fellowship program was established by the US Department of Energy, Office of Fusion Energy, to encourage outstanding students interested in fusion energy technology to continue their education at a qualified graduate school. The basic objective of the MFET Fellowship program is to ensure an adequate supply of scientists in this field by supporting graduate study, training, and research in magnetic fusion energy technology. The program also supports the broader objective of advancing fusion toward the realization of commercially viable energy systems through the research by MFET fellows. The MFET Fellowship program is administered by the Science/Engineering Education Division of Oak Ridge Institute for Science and Education. Guidance for program administration is provided by an academic advisory committee.

Fusion Fellowships – Stipends

- http://www.orau.gov/fusion/
- http://science-education.pppl.gov/Nuf/Index.html

HEDP Opportunities for IFE

Presentation to the Inaugural IFE Science and Technology Strategic Planning Workshop
San Ramon, California

Ed Synakowski
Fusion Energy Program Leader, LLNL

April 27, 2007

Work performed under the auspices of the U.S. Department of Energy
by the University of California, Lawrence Livermore National Laboratory
under Contract No. W-7405-ENG-48.

UCRL-PRES-230726

Acknowledged: Many of you felt frustrated by the HEDP questions

- Our group had to work through the question of "Why are we dealing with these questions? We want to get on with it."

- One group changed the questions substantially, but I think still got to a very constructive place

- All of this is understandable - I share the frustration

I believe the answer is that $HEDLP^2$ is where a new opportunity resides

- We've been given a clarion call - an explicit invitation to describe our vision for how to use major facilities for IFE-related HEDP research
- I believe we will serve our interests in IFE well if we answer that bell
- It is perfectly consistent to do this in parallel with working hard towards establishing a community vision for an integrated IFE program - and HEDP should be part of that vision

The opportunity is clear

- From the invitation:
  - "On behalf of Under Secretary of Science Dr. Raymond L. Orbach, we are writing to invite you to a joint NNSA/Office of Science workshop on High Energy Density Laboratory Plasmas (HEDLP). The workshop will be co-chaired by Dr. Robert Rosner, Director, Argonne National Laboratory, and Dr. John Browne, former Director, Los Alamos National Laboratory. The purpose of the workshop is to formulate a proposed path forward for development of HEDLP within the Department. Further information is contained in the attached workshop charter…"
    - Dr. Raymond L. Fonck
    - Dr. Christopher J. Keane

The workshop charter spells out the opportunity

- “Assess frontier experiments on major HED science facilities, with a particular focus on NIF and the opportunities there to perform experiments related to the science of high energy density plasmas... Because the various subfields of HED science are very much intertwined and interconnected, the discussions at the workshop may include the support and complementary use of smaller facilities, including, but not limited to, Omega, Z-R, Trident, Jupiter, NDCX, and other research facilities using lasers, pulsed power and particle beams. Discussions and assessment of the scientific opportunities in these smaller facilities should be included in this Workshop. Potential follow-on workshops should be identified to address the HEDP opportunities at these facilities in more detail. For planning purposes, subject to subsequent budget approvals and appropriations, an initial $25 million per year program would be considered at the workshop.”

My intent: convey to the upcoming workshop that this community is eager to take advantage of these opportunities

- We see this as an essential **part** of an urgent mission critical to meeting world energy, climate, and security needs

- Indeed, from one group:
  - "A golden opportunity exists to leverage the nation's investment, in preparation for the success of the NIF, to direct our attention to the energy-related HEDLP questions that will enable us to achieve that goal"

Barnard breakout group

- And from another
  - "IFE is an underlying goal of the ICF and HEDP communities. For the most part, the communities are working together toward the IFE goal"

Betti breakout group

The questions were…

- What are the HEDP questions that can be addressed in IFE-relevant NNSA and OFES facilities? Which questions are directly relevant to IFE? What types of IFE relevant experiments can be done on NNSA ICF facilities?

- How does addressing these questions enable progress in IFE?

- What opportunities exist that can be captured with growing budgets?

- How are the IFE/ICF/HEDP communities working together to maximize use of limited resources to advance the science of IFE? What obstacles exist? How can these working relationships be improved?

Intent of the questions: discuss the intersection between HEDLP^2 and IFE

- Ron Davidson reminded us that the HEDLP^2 community is very broad

High Energy Density Physics

Principal Research Thrust Areas Identified by the National Task Force

Astrophysical phenomena

Inertial fusion energy fast ignition

Heavy-ion-driven HEDP and fusion

Fundamental physics of high energy density astrophysical phenomena

Laboratory astrophysics

Radiative hydrodynamics

HEDP with ultrarelativistic electron beams

Inertial confinement fusion

Characterization of quark-gluon plasmas

Laser excitation of matter at the relativistic extreme

Materials properties

Attosecond physics

Compressible dynamics

Compact high energy particle acceleration

Ultrafast, high-peak-power x-rays

Intent of the questions: discuss the intersection between HEDLP^2 and IFE

- … and that the intersection with IFE science needs is great

High Energy Density Physics

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One cut: 12 areas of HEDP relevant to IFE (1 of 2)

HEDLP topic	*IFE areas advanced*
– 1. Charged-particle transport in conditions ranging from WDM to thermonuclear conditions	Fast ignition, Heavy ion fusion
– a. Ion transport & stopping	
– b. Charge state of ions in WDM	
– c. Hot-electron transport & stopping	
– 2. Transport properties of WDM	Fast ignition, MIF, ICF (foam)
– 3. LPI	ICF, Fast ignition
– 4. Physics enabling next Gen x-ray light sources	Diagnostics
– 5. Rad-hydro	IFE
– a. Imprint	
– b. Instability growth	
– c. Solid state surface conditions	
– d. Physics of hohlraums	
– e. Rad flow	
– f. Fuel assembly	
– 6. Non-plasma EOS	IFE
– 7. Physics in strong fields	MIF, Pulsed-power IFE
– a. Transport	
– b. Dynamics	
– c. Magnetized & collisional	

Fernandez break-out

Another cut: 12 areas of HEDP relevant to IFE (2 of 2)

HEDLP topic	*IFE areas advanced*
8. Physics of intense beams	Heavy ion fusion, fast ignition
– a. Neutralization	
– b. Compression	
– c. Beam-plasma interactions / instabilities	
– 9. Mechanisms/physics of laser/plasma accelerators	Fast ignition, diagnostics
– a. Generation of ions	
– b. Acceleration	
– 10. Generation of intense x-rays	Indirect drive, fast ignition
– 11. Thermonuclear burn	IFE
– a. T-lean	
– b. Non-LTE transport in burning plasma	
– c. Geometric effects	
– d. X-sections at low E	
– 12. Plasma jets	MIF, Indirect drive, IFE
– a. Deceleration	
– b. Interpenetration	
– c. Generation	
– d. Interactions with solids	

Other questions identified…

- →What takes to ignite high-density magnetized and unmagnetized thermonuclear fuel in a laboratory?
- →What is the range of T, n and B that can be created in HEDP plasmas?
- →What is the fast particle generation and transport in HEDP plasmas?
- →What are the EOS and other material properties (electrical conductivity, opacity etc) under extreme HEDP conditions?
- →What are the energy transport properties in ultra high pressure magnetized and unmagnetized plasmas?
- → How can cool (subthermonuclear), high -density and areal density fuel be assembled in the lab.

Betti breakout group

Other questions identified…

- → Can astrophysical codes be validated in HEDP laboratory plasmas?
- → Can WDM physics be explored in HEDP laboratory plasmas?
- →Can HEDP plasmas be assembled to achieve high enough density to explore strongly coupled and/or degenerate plasma regimes?
- →How an IFE relevant target should look like.
- →How can IFE-relevant gains be achieved?
- →Damage and survivability to high radiation and particle fluxes?

There were many ways in which a strengthened HEDLP program was seen as helpful to IFE

It was noted that an effective HEDLP program can benefit IFE in the following ways:

- 1. Broad based-mission that attracts talent
- 2. Broadens the interest (including the public) & funding base
- 3. Cross fertilization & innovation into IFE from other communities
- 4. Respect from other scientific communities
- 5. Opportunities for multi-faceted modeling validation
- 6. Increased credibility
- 7. Drive diagnostic development
- 8. Increased scientific base for IFE success & innovation
- 9. Lead to basis for assessment of IFE technologies

My thoughts: Using the basis set from the Task Force report, and explore a few examples

Go a couple of layers into the scientific questions & the facilities that are and might be involved

High Energy Density Physics

Principal Research Thrust Areas Identified by the National Task Force

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Magnetized HEDP plasmas

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Ultrafast, high-peak-power x-rays

Something expressed by some in the groups, and throughout the workshop

- Cross-cutting, powerful event for all forms of IFE: ignition on NIF
  - Will teach us about the essential scientific viability of fusion in the laboratory
  - What we will learn will have a cross-cutting impact across any laser, ion, or Z approach to IFE

Basic theme: NNSA/OFES facilities are essential to the validation and verification of many scientific issues central to IFE

- *Wide range of device types* provides an ideal platform for validation and verification of HEDP science needed for IFE
  - — They provide scientific leverage: Push hard on extrema in parameters, LPI, target configuration

    ==> field test any theories that will be relied upon in future IFE applications. The successful theory will need to allow not only interpolation but also extrapolation in HEDLP

- One group's expressions of this: a strengthened HEDLP effort will help enable the accurate assessment of the viability of drivers, target and chamber configurations, fuel cycles, and methods of power conversion

We can convey to the community that the science of HEDLP can have a deep impact on the attractiveness of IFE

- For example: Introduce to the upcoming Workshop the science of the fast ignition as a *cross-cutting* opportunity that may have high impact via gain and potentially system architecture *and* is great, multiscale science
  - — Describe the scientific challenges - enormous range of scales challenge and need to make the hard measurements - and the opportunity to take advantage of computational resources from the university scale to the most powerful systems
  - — Describe a V&V effort that could use the full range of facilities - university, including petawatt, NNSA high power laser, Omega EP, NIF - where scientific ideas, including their scalings, can be tested

- Introduce to them the potential value of advanced targets studies for IFE that can be deployed on NIF

Another high level question for IFE comes from HIF and connects to other approaches

- Motivating question to use as an example: can ion beams be compressed and focused to reach ignition conditions and first explore the WDM regime and ulimately to reach ignition?

- Motivate this by underscoring that NIF and Z studies can substantially inform the development of indirect drive HIF targets

- Underscore the astrophysics accessible in WDM studies

- Highlight the potential of OFES facilities as user facilities (NDCX-II, e.g.)

All groups grappled with workforce issues, and the opportunities that go with a growing HEDLP effort

- It was widely recognized that a strong and growing HEDLP program will attract smart young minds to the field essential to the development of IFE, enabling maximal use of HEDLP facilities

- Cuts both ways: it was felt strongly that a strong, healthy IFE program can draw researchers to the field of HEDLP

There were elements in the discussions regarding obstacles

- The question was raised as to how the small-institution PI best couples with the large as well as the small facilities
  - Discussed was the need for interfaces between the larger facilities and the outside PI - to hand-hold through the experiment development process, to provide modeling support, and diagnostic and modeling interpretation after a campaign

Some take-away messages for the committee…

- The reason many are involved in HEDLP is in fact the IFE vision. IFE-related research should be a critical component of any national HEDLP strategy - it will motivate researchers now in the field and will draw others in

- HEDLP is an essential part of a larger strategic vision for IFE. It will help establish the scientific basis for IFE and the underpinnings of an attractive vision

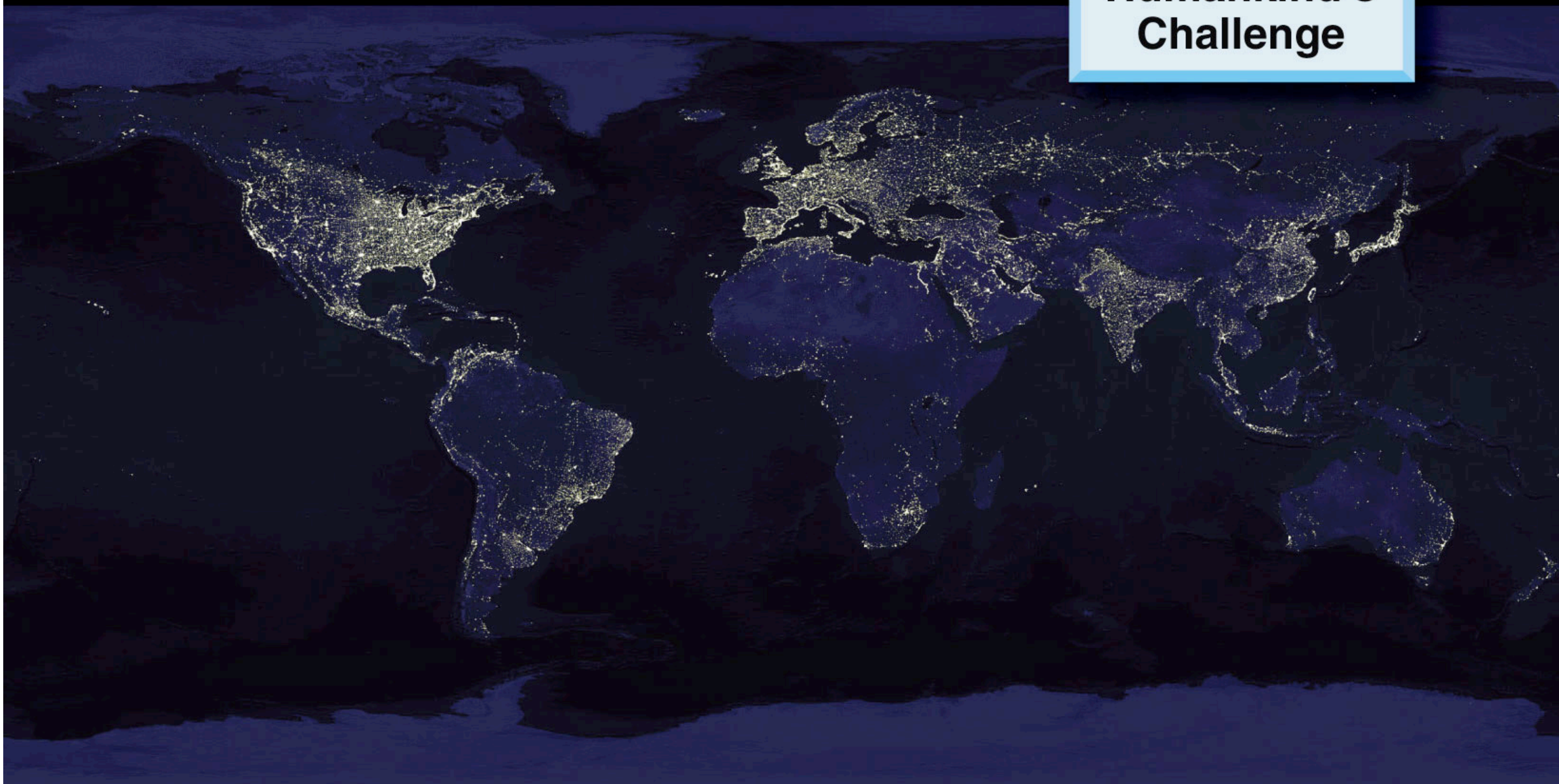
- The wide range of facilities available can combine with good diagnostics and advanced computation to provide a powerful test bed for IFE-related physics.
  — Ignition-scale experiments to university scale, plus the wide range of configurations, enable powerful tests of theoretical ideas central to IFE

Thanks so much. This has been a great experience. Let’s build on it.

- I could easily imagine follow-up workshops to…
  - — consider the potential role of international collaboration in a U.S. strategic vision for IFE
  - — develop, over two or several meetings, a community white-paper outlining an IFE breakout strategy
  - — challenge ourselves with open exchanges regarding strengths and pitfalls of proposed visions
  - — discuss getting industry views of our vision
  - — develop a detailed HEDP strategy to take advantage of the present-day opportunity

- Will work with the steering committee to develop an agenda and timetable and agenda for a follow-up

Clean Energy: Humankind's Challenge



IFE Planning Breakout Session Summary

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The following is a summary of the IFE Planning Breakout Session that was conducted on Thursday, April 26 and presented by Steve Dean on Friday, April 27. This summary contains main points that were made in four different subgroups and compiled by the four breakout group leaders. It includes minor editing that occurred after the workshop.

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Questions presented to the breakout group to stimulate discussion:

1. What are the elements of a compelling breakout strategy for IFE?
2. What advances have to be made to make such a strategy credible?
3. What advances can only be made with increased funding?
4. Have views of an IFE development path changed since the IFE FESAC report? If so, how?

- IFE, with the exception of some aspects of HIF, has been funded by Congressional add-ons and Laboratory Directed Research and Development (LDRD). NNSA is focused on single shot facilities and technologies; OFES is focused on fusion "science" and not energy development. A "home" is needed in DOE that is interested in fusion energy development that would be interested in receiving and implementing an IFE strategic plan. This will require a change of policy in the Executive Branch. Previous fusion community and DOE review panel studies all have shown that MFE and IFE are equally credible as fusion energy approaches. Yet current DOE policy, whether deliberate or not, has the effect of holding back IFE development.

- A defining event for triggering a breakout for implementation of an IFE plan is the anticipated achievement of ignition on NIF in the 2010-2012 time frame. The DOE should be prepared to capitalize on that success. Therefore, specific programs should be carried out in the immediate future in order to be prepared to respond to that event. These include rep-rated driver, target and chamber development, computation and systems studies for IFE. The funding required for these efforts, pre-NIF ignition, is modest compared to the currently funded ICF efforts, approximately $60-70M per year. In recent years, funding for IFE specific research (~$25-30M/yr) has been entirely due to year-to-year Congressional actions. DOE has no visible plans to support such efforts. "Energy-related" research in the new HEDLP program would be complementary to IFE but is no substitute for a focused IFE effort.

- Concerns about global warming or an oil crisis could also provide a trigger for requesting serious fusion energy development.

- The cornerstone of an IFE breakout strategy is a program aimed at construction of a rep-rated IFE fusion test facility. The detailed configuration of this facility is not fixed yet, but it is envisaged as the last major facility prior to a Demo. As part of a program leading to construction, subsystem prototypes and component development would be required in order to finalize design and proceed to construction. These include driver development for lasers, heavy ions and Z-pinch drivers, target design and fabrication, chamber technologies and detailed conceptual design. Modularity and separability of subsystems lend themselves to a cost-effective development path as part of a fusion test facility program.

- The readiness to proceed with a fusion test facility, post NIF ignition, depends heavily on obtaining a stable source of funding. Currently funding for all aspects of IFE is in doubt every year.

- As part of the IFE strategic plan, non technical questions should be addressed that answer issues that most likely would be raised by non-technical people, such as why is IFE a desirable product for society.

- The plan should contain items such as vision, detailed R&D tasks, budget and schedule. The plan should stress the cost effectiveness of IFE development in light of the substantial science and technology base being developed by NNSA. It should also describe the potential for a faster development path relative to some previous fusion plans. Since replacement of existing power plants and construction on new ones will likely begin in earnest around 2050, fusion should attempt to put forth a plan that would have a commercial power plant ready for deployment around that time, if possible.

- The IFE strategic plan should include partnerships among labs, universities and industry. Industry involvement in the development will make it more likely that the IFE program will lead to a commercial product. Power plant studies are also needed to provide an attractive long range vision for IFE and to highlight areas in which improvements are needed.

- There are mixed opinions on the extent to which IFE should align itself with fission. While fusion likely has something to offer, it is not clear that the fission community thinks it needs fusion. Nevertheless there are large areas of technological overlap between fusion and fission nuclear. There should be some coordination of the research efforts.

- While the U.S. IFE community should collaborate with the growing international IFE effort, the plan should be capable of being implemented domestically and focused on a product that would be attractive in the U.S. market.

- The general features of IFE described in the 2004 Linford FESAC IFE panel report are still current. However, much progress has been made since then. For example, more serious efforts are underway in the U.S. and elsewhere on fast ignition, more attractive designs and techniques for irradiating targets have been proposed, and a shortened development path has been suggested.

- The current DOE plan to emphasize and expand efforts in HEDLP will strengthen the physics basis for IFE. It is, however, not a substitute for the more urgent need for energy-related and IFE-focused efforts on IFE development.